PB89-126569

Advanced Utility Simulation Model
Energy and Employment Impacts Module
(Version 1.0)

Illinois Univ. at Urbana-Champaign

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Oct 88

U.S. Department of Commerce
National Technical Information Service
NTIS

PB89-126569

EPA/600/8-88/071g
October 1988

ADVANCED UTILITY SIMULATION MODEL
ENERGY AND EMPLOYMENT IMPACTS MODULE
(Version 1.0)

by

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EPA Cooperative Agreements
CR808514 and CR809461

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This study was conducted in cooperation with the
National Acid Precipitation Assessment Program

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RESEARCH TRIANGLE PARK, NC 27711

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/8-88/071g		PB89 126569/AS

4. TITLE AND SUBTITLE Advanced Utility Simulation Model, Energy and Employment Impact Module (Version 1.0)	5. REPORT DATE October 1988 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) B. Hannon, R. Jackson, and D. Kennedy	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS University of Illinois at Urbana-Champaign* 901 South Mathews Avenue Urbana, Illinois 61801	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO. Cooperative Agreements CR808514 and CR809461
12. SPONSORING AGENCY NAME AND ADDRESS **EPA, Office of Research and Development** Air and Energy Engineering Research Laboratory **Research Triangle Park, NC 27711**	13. TYPE OF REPORT AND PERIOD COVERED Final: 9/82 - 8/83 14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES AEERL project officer is Larry G. Jones, Mail Drop 62, 919/541-7716. (*) Universities Research Group on Energy Project Office.

16. ABSTRACT The report is one of an 11-volume series that describes the initial development of the Advanced Utility Simulation Model (AUSM), one of four stationary source emission and control cost forecasting models developed in 1984 for the National Acid Precipitation Assessment Program (NAPAP). The AUSM model projects air pollution emissions (SO2, NOx, and particulate matter), costs of electric generation, electric rate schedules, costs of emissions control, fuel consumption by type, electric generating technology construction, and generating technology utilizations for existing and new electric generating units by state. The initial version of AUSM (Version 1.0) was delivered between November 1984 and August 1985. Further development of the AUSM model between 1985 and 1988 has resulted in the development of Versions 2.0 and 3.0. Reports describing Revisions 2.0 and 3.0 are also part of this series.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Sulfur Dioxide	Pollution Control	13B 07B
Utilities	Nitrogen Oxides	Stationary Sources	
Emission	Fuels		14G 21D
Cost Analysis	Electric Power Demand		14A
Simulation			20C
Forecasting	Mathematical Models		12A

18. DISTRIBUTION STATEMENT **Release to Public**	19. SECURITY CLASS *(This Report)* **Unclassified**	21. NO. OF PAGES 29
	20. SECURITY CLASS *(This page)* **Unclassified**	22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

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ABSTRACT

The Advanced Utility Simulation Model (AUSM) is one of four stationary source emission and control cost forecasting models developed by the Air and Energy Engineering Research Laboratory (AEERL) for the National Acid Precipitation Assessment Program. The AUSM model projects air pollution emissions (sulfur dioxide, nitrogen oxides, and particulate matter), costs of electric generation, electric rate schedules, costs of emissions control, fuel consumption by type, electric generating technology construction, and generating technology utilizations for existing and new electric utility generating units by state.

The AUSM model was originally developed by the Universities Research Group on Energy (URGE) and delivered to the Environmental Protection Agency (EPA) in 1984. This document is one of several in this series that describes the initial development work of the AUSM model by URGE and its continued development by the Science Applications International Corporation (SAIC) research team. The initial version of AUSM, designated by EPA as Version 1.0, was delivered by URGE in November 1984 and August 1985. Further development of the AUSM model by SAIC in the 1985-1988 period has resulted in the development of Versions 2.0 and 3.0. Reports describing these revisions by SAIC to the initial version 1.0 of AUSM are also part of this series.

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PROGRAM DESCRIPTION: GENERAL PROGRAM PACKAGE

This portion of the URGE model is written in a set of 6 separate Fortran programs, named:

FDCAL
EPSCAL
LAMCAL
POLCAL
DIRLABC
DIRLABM

Each of these programs must be run in the sequence shown above. The reason for the sequence dependence is that output from previous programs are used in the following programs. Each program is run once per scenario year, except POLCAL which may be run for low and high electric industry pollution data, and FDCAL, which may be run for low and high employment GNP values.

All the data associated with these programs are binary files. The description of the data format is included with the individual program description which follows.

Appendix A — FDCAL
Appendix B — EPSCAL
Appendix C — LAMCAL
Appendix D — POLCAL
Appendix E — DIRLABC
Appendix F — DIRLABM

The results of this portion of the URGE model are based upon energy intensities and final demand data for 1972. An updated version of the model using the most recent BEA and energy data for 1977 can be obtained by replacing the 1972 files with their 1977 equivalent contained in the following files:

U77C88 - the 1977 BEA USE Matrix in $1972 (Replaces U72X88)

V77C88C - the 1977 MAKE Matrix in $1972 (Replaces V72X88)

D77C88 - the 1977 Direct Energy Transactions Matrix (Replaces D72C88)

F77C88 - the 1977 Final Demand Portion of the Use Matrix in $1972
(Replaces F72C88)

AL77 - the vector of primary energy coefficients for 1977
(Replaces AL72)

Each of these files is in binary form and each is accepted by the URGE programs. They are stored in account 3IMPERG.

APPENDIX A

PROGRAM DESCRIPTION: FDCAL

BASE DATA (SCENARIO INDEPENDENT)

INPUT FILES	FORMAT	SIZE ORGANIZATION
FD	binary file (see note)	8 x 88 column = record
CST1	" "	69 x 89 column = record
CST2	" "	69 x 89 column = record
CST3	" "	69 x 89 column = record
CST4	" "	69 x 89 column = record
CST5	" "	69 x 89 column = record
CST6	" "	69 x 89 column = record
CST7	" "	69 x 89 column = record
CST8	" "	69 x 89 column = record
CST9	" "	69 x 89 column = record
DEF	" "	1 x 88 column = record
FFI	" "	7 x 5 column = record

SCENARIO DATA

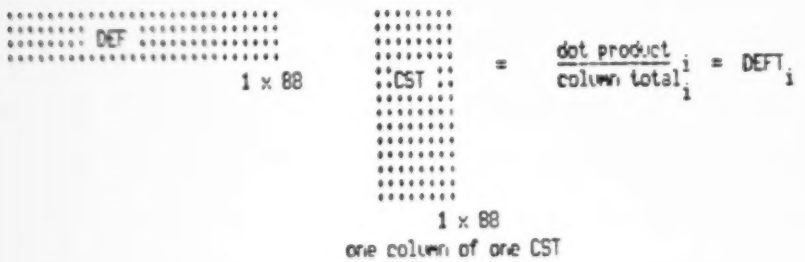
CE	" "	9 x 69 column = record
PCEE	" "	1 x 5 column = record
GNP	" "	1 x 9 column = record
BFD	" "	1 x 88 column = record

Note: Each file contains a header record (no. of records, record length, date, and description) then binary data organized as indicated,

PROGRAM DESCRIPTION

FDCAL uses a 9 activity final demand matrix as input (see below). This matrix is reorganized into 11 activities (see below). The CSTs (construction costs) are a set of 9 matrices that give the dollar value of 88 commodities used by 69 types of electric power plants in one of 9 periods of construction. The 89th entry of each CST record is the column (record) total. The CE

(construction expenditures) matrix is in 1980 dollars, therefore it must be converted to 1972 values. This dollar "deflation" is performed by using commodity deflator in the DEF input file. These are 88 order commodity deflators that represent 1972 values in 1980 dollars, i.e. the deflators are all greater than or equal to one.



$$\frac{\text{dot product}}{\text{colum total}}_i = \text{DEFT}_i$$

This operation is performed for all columns of each CST matrix. The result is 9 x 69 matrix which is used to adjust the CE matrix (construction expenditures). The DEFT matrix is also output to a local file which must be saved for the DIRLABC program. The ratio of CE to the CST column total is then used to adjust the elements in the column. This is done for each technology in each period of construction. The result is the actual expenditure for each technology in each of 9 stages of construction. The column are then added element by element to form ECAP, total electric construction expenditure a 1 x 88 vector. THETA, which is the matrix of CST column totals, is output for uses in the DIRLABC program.

The input FD matrix (final demand) is column totaled and stored in the program as FDT for the 9 activities. The first 5 rows of the PCE (personal consumption expenditures) columns are summed and subtracted from the PCE column totals, then the first five rows of the PCE columns are zeroed. The input FD matrix is in all dollars and must be converted to BTUs in the 5 energy rows. The PRI matrix represents the ratio of 1972 BTU to dollar values for 7 activities of final demand. The PRI matrix contains only one PCE activity, this is use to convert all three PCEs of the input final demand.

The electric capital vector is substracted from the capital column (GPDI) in the input final demand matrix. The electric capital vector is the first column of the new final demand matrix and the adjusted capital vector is the second column. The GPDI column total is also adjusted by the total of the electric capital vector. The three PCE activities form the next three columns. The personal consumption of energy, which is scenario input, is the next column (see below). The remaining columns of the new matrix are formed by the remaining columns of the input final demand. Each of the original 9 activities is normalized by its column total (FDT), by dividing each of the 88 elements in the column by FDT.

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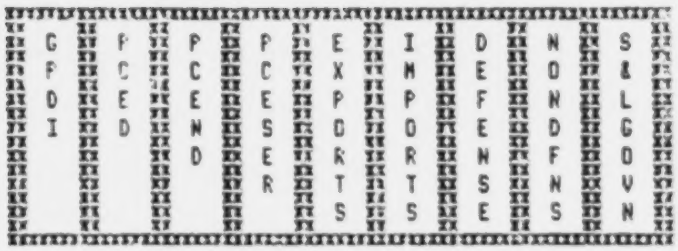
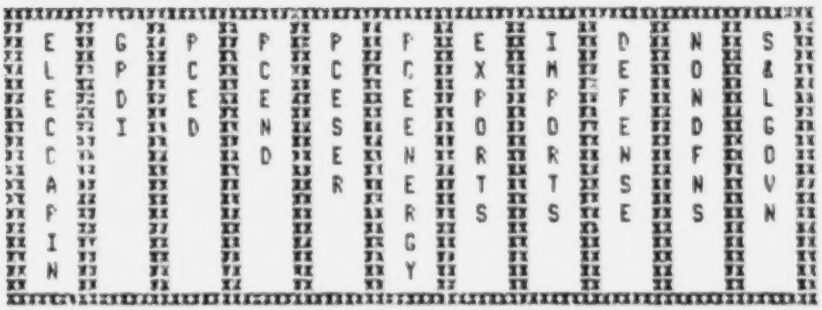
INPUT MATRIX



RESULTANT MATRIX



The resultant matrix has 11 activities which have BTU/$ in the first five rows and $/$ in the remaining 93 rows.

The GNP input file is the total dollar value for 9 final demand activities to which the 9 final demand activities will be eventually adjusted. Before the GNP data is used the following corrections are performed. The CETT (total construction expenditure) from the GNP GPDI value. The GNP PCE values are adjusted by the corresponding PCE activity total energy dollar value. The sum of the GNP values is calculated and the sum of the 9 FDT is subtracted to

form a DELTA GNP. The operator is then given the opportunity to distribute the DELTA among the original 9 activities by entering fractions as questions are asked. The GNP vector is adjusted by the fraction of the DELTA GNP specified.

The normalized final demand is now "unnormalized" by the corresponding GNP value. This produces an adjusted 88 order 9 activity final demand matrix for the original data plus two new activities described previously.

The columns are summed together and output to a local file , FDOUT, which must be saved. FDOUT represent the sum of all final demand activity at 88 order.

OUTPUT FILE	FORMAT	SIZE	ORGANIZATION
FDOUT	binary (see note)	1 x 88	column = record
DEFT	" "	9 x 69	column = record
THETA	" "	9 x 69	column = record

Note: The files contain a header (no. of record, record lenght, date and scenario info) then data stored one column of a matrix equals one record on file.

The FDOUT file is used by the EPSCAL, LAMCAL, and POLCAL programs as input. The DEFT and THETA are used in the DIRLABC program.

The results of the scenario run are also output to a character file, LIST. LIST provides a formatted hard copy report of the run. The FDOUT file of a previous run can be input to the program via GET,BFD=XXXX for comparison with the current run.

APPENDIX B

PROGRAM DESCRIPTION: EPSCAL

BASE DATA (SCENARIO INDEPENDENT)

INPUT FILES	FORMAT	SIZE	ORGANIZATION
U	binary file (see note)	88 x 88	column = record
V	" "	" "	column = record
FD	" "	11 x 88	column = record
DET	" "	5 x 99	row = record
ALPHA	" "	1 x 5	column = record
MV	" "	29 x 88	column = record
TS	" "	1 x 29	column = record
DEF	" "	1 x 1	

SCENARIO DATA

BEFS	" "	1 x 6	column = record
FDFS	" "	1 x 88	column = record
CNEW	" "	1 X 1	
S	" "	1 x 29	row = record
FU	" "	1 x 5	column = record

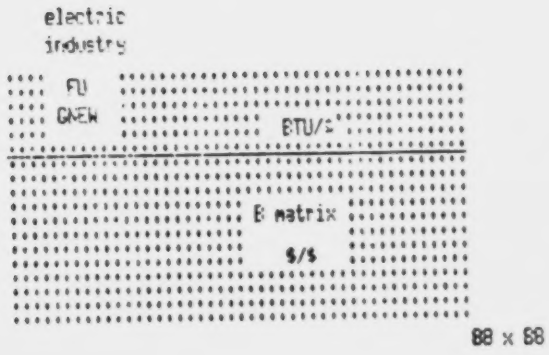
Note: Each file contains a header (no. of records, record length, a description field- possibly blank) as first record, then binary data organized as shown.

PROGRAM DESCRIPTION

The input data is entered into the program through a set of GET,NAME=<filename> statements at the beginning of the program. For example, U is the Use Matrix in the calculation, the particular filename for the Use Matrix may be U72X88. Both base data and scenario dependent data are entered in this manor. What follows is a general description of the program's use of the input data.

The S vector represents the total sales of electricity by one of 29 types (technologies) of plants producing electricity in BTUs. The sales vector varies by scenario and therefore a new file must be specified in the program get statement. The MV Matrix represents the typical annual use of 88 commodities by each of the 29 technologies. The energy commodities (first 5 entries in each record) are in BTUs, while the remaining 83 commodities used are represented in 1972 dollars. The TS (typical annual sales) vector contains 29 BTU values which are used to normalize the MV matrix, i.e. one value is used to divide each element of one column. The S vector is the used to multiply each technology column, which gives the total of each technologies use of the 88 commodities. The matrix is summed acrossed the 29 technologies, resulting in the total use of 88 commodities by the electric industry.

The FU matrix represents the primary use of fuel to generate electricity for 5 types of fuel by all types of electric plants in BTUs. This data is added to the 5 energy use value calculated above by fuel type. The 5 element vector is then normalized by total dollars sales of electricity (total electric industry output - g) which is given in 1980 dollars. This scenario data is entered into the program via the GNEW input file. Before the GNEW can be used it must be converted in to 1972 equivalent dollars by the use of an industrial deflator. The deflator is entered into the program by the DEF file. At this point the 5 element vector will directly substituted into the first 5 positions of the fourth column of the B matrix as shown below.



The following discussion show the mathematical developement of the B matrix and finally the development of the energy intensities

$$\sum_{j=1}^{88} U_{ij} + FD_{ij} = q_i$$

where q_i is the row sum vector which is diagonalized to form a matrix q, the total commodity output. The matrix is inverted and used to form the Market Shares matrix, D, as shown.

$$D = V \quad q^{-1}$$

$$\sum_{j=1}^{88} V_{ij} = g_i$$

where g_i is the row sum vector which is diagonalized to form a matrix g, total industry output. The matrix is inverted and used to form the Industry Input matrix, B, as shown:

$$B = U \quad g^{-1}$$

The resulting B and D matrices are in mixed units. The energy commodity rows of B are BTU/dollar, while the rest of the matrix is dollar/dollar or unitless. The D matrix units are dollar/BTU for the energy commodity columns, while the rest of the matrix is dollar/dollar or unitless.

The B and D matrices are used in the formulation of the I-O model equation.

$$\epsilon = (I - BD)^{-1}$$

The model formulation equation produces the following matrix .

Energy Commodities	$\frac{BTU}{BTU}$	$\frac{BTU}{\$}$
Non-Energy Commodities	$\frac{\$}{BTU}$	$\frac{\$}{\$}$

The top five rows of the above matrix, labeled Energy Commodities, are the Energy Intensities, , of each of the five energy types used in each industry. The complete matrix shown above is stored at the end of the program in a local file named BD. Also the D matrix and GE72D, deflated electric industry total dollar output, are in the local file D and GE72D respectively. These files must be saved for use in the LAMCAL and POLCAL programs.

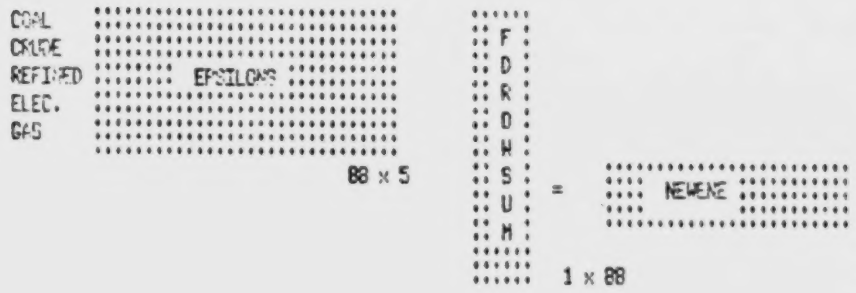
The Primary Energy Intensity, ϵ_p, for each industry is calculated by multiplying the Energy Intensity vector for each industry by an α vector which is the input file ALPHA. The ϵ_p are stored in the local file TP at the end of the program and may be saved. The α_i is the fraction of the direct energy for the particular fuel type i which is taken directly from the U. S. earth by that energy sector. For example, electricity was generated from the primary energy types of coal, crude and natural gas. A factor was formulated to account for the electricity which was generated from the "ground", such as hydro and nuclear power. These quantities were transformed into equivalent fossil fuel units at the average efficiency of the existing fossil fuel power plants. The resulting α vector entry represents the portion of electricity produced from sources other than primary energy inputs.

OUTPUT FILE	FORMAT	SIZE	ORGANIZATION
BD	binary (see note)	88 x 88	column = record
D	" "	88 x 88	column = record
GE72D	" "	1 x 1	
NEWENE	" "	1 x 6	column = record

Note: The files contain a header (no. of record, record length, date, and description) as the first record then data.

The output files BD, D, GE72D and NEWENE must be saved at the end of a run. The BD, D and GE72D are use by other programs of the model. The NEWENE file is a binary file that contains the total energy by fuel type and the total primary energy. This may be compared to the new output of a run, by placing the name of this file in the GET,BEPS=XXX statement.

The output of the FDCAL program FDOUT is used as input to calculate the energy total data.



The results of the program are output to a character file named "LIST". By printing LIST, a formatted hard copy of the scenario run can be obtained.

APPENDIX C

PROGRAM DESCRIPTION: LAMCAL

INPUT FILES	FORMAT	SIZE	ORGANIZATION
BD	binary file (see note)	88 x 88	column = record
D	" "	" "	column = record
LAB	" "	40 x 88	column = record
	SCENARIO DATA		
BLAM	" "	1 x 40	column = record
FDFS	" "	1 x 88	column = record

Note: Each file contains a header (no. of records, record length, date, and description) then binary data stored one record equals one column of a matrix.

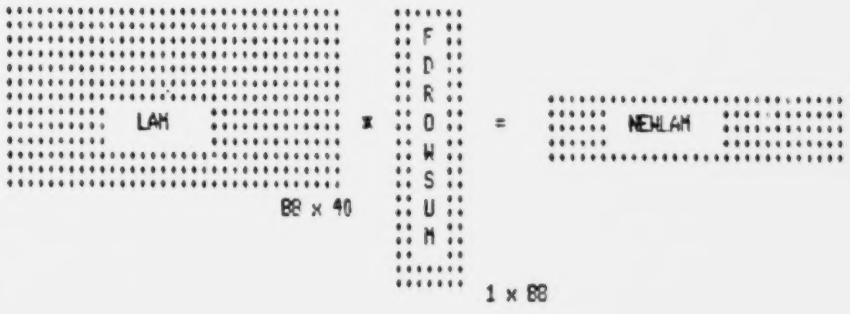
PROGRAM DESCRIPTION

Lamcal use the output file of the Epscal program, BD and D , to calculate the labor intensities (lambda). The program premultiplies the BD matrix by the D matrix, then the product by the labor matrix. The output is placed in the local file file LAM, to be saved at the end of the calculation.

OUTPUT FILE	FORMAT	SIZE	ORGANIZATION
LAM	binary (see note)	40 x 88	column = record
NEWLAM	" "	1 x 41	column = record

Note: The files contain a header (no. of record, record length, date, and description) then data stored one column of a matrix equals one record on file.

The NEWLAM file maybe saved and used in the next scenario pass as input by the GET,BLAM=XXXX. The current data is compared to BLAM and a report is generated. The character file LIST maybe printed for a hard copy report. The NEWLAM data is calculated as follows.



The 41st element of the the NEWLAM files is the sum of the 40 elements.

APPENDIX D

PROGRAM DESCRIPTION: POLCAL

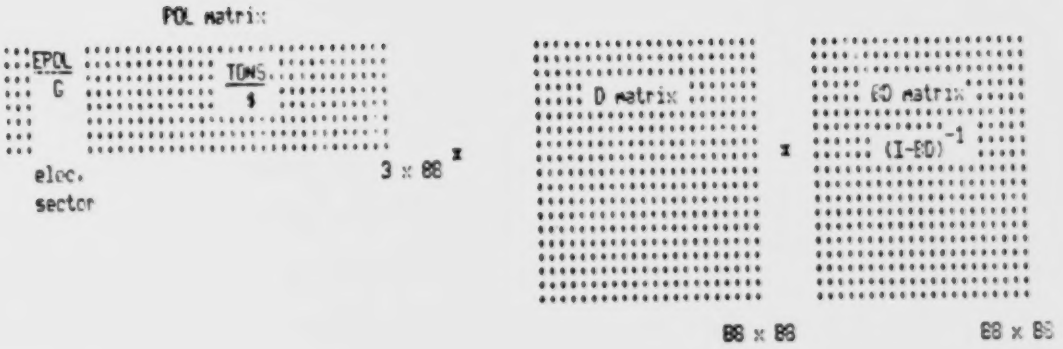
BASE DATA (SCENARIO INDEPENDENT)

INPUT FILES	FORMAT	SIZE	ORGANIZATION
BD	binary file (see note)	88 x 88	column = record
D	" "	" "	column = record
POL	" "	40 x 88	column = record
G	" "	1 X 1	
	SCENARIO DATA		
EPOL	" "	1 X 5	column = record
BPOL	" "	1 X 3	column = record
FORS	" "	1 X 88	column = record

Note: Each file contains a header (no. of records, record length, date and description) then binary data stored one record equals one column of a matrix.

PROGRAM DESCRIPTION

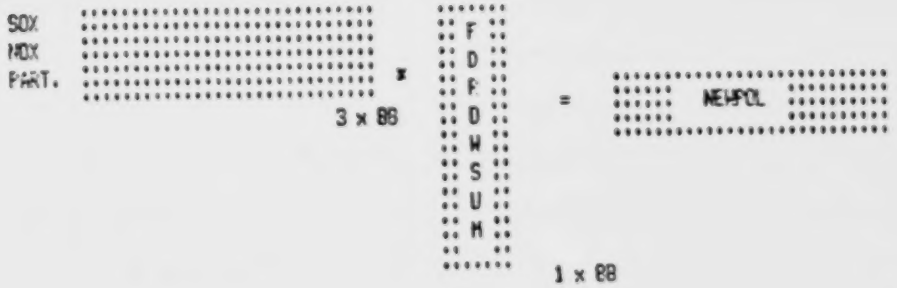
Polcal uses the output file of the Epscal program, BD, D and G to calculate the pollution intensities (roe). The program is run twice per scenario year; once for low and once for high electric utility industry pollution data values.



OUTPUT FILE	FORMAT	SIZE	ORGANIZATION
ROE	binary (see note)	3 x 88	column = record
NEWPOL	" "	1 x 3	column = record

Note: The file contain a header (no. of record, record length, date and description) then data stored one column of a matrix equals one record on file.

The NEWPOL output file should be save for use in a later run of POLCAL. It can be read in by the GET,BPOL=XXXX. The values will then be compared to the present run and report written. The report is placed in a character file which may be printed.



APPENDIX E

PROGRAM DESCRIPTION: DIRLABC

BASE DATA (SCENARIO INDEPENDENT)

INPUT FILES	FORMAT	SIZE	ORGANIZATION
DEF	binary file (see note)	9 x 69	column = record
CET	" "	" "	column = record
LAB1	" "	69 x 40	column = record
LAB2	" "	69 x 40	column = record
LAB3	" "	69 x 40	column = record
LAB4	" "	69 x 40	column = record
LAB5	" "	69 x 40	column = record
LAB6	" "	69 x 40	column = record
LAB7	" "	69 x 40	column = record
LAB8	" "	69 x 40	column = record
LAB9	" "	69 x 40	column = record

SCENARIO DATA

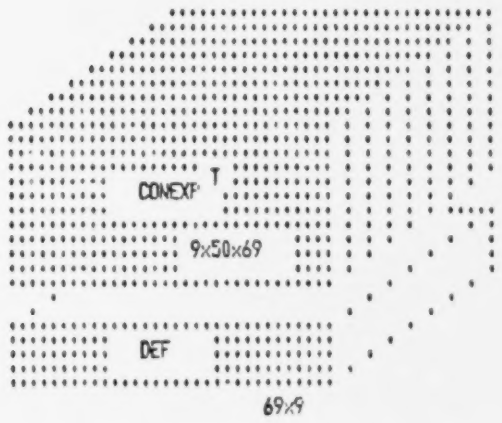
CONEXP	" "	450 X 69	column = record

Note: Each file contains a header (no. of records, record length, date and description) then binary data stored one record equals one column of a matrix.

PROGRAM DESCRIPTION

DIRLABC program performs the direct labor calculation for the construction of 69 electric generating technologies in each of 50 states, whose order is arbitary in the data base, but consistant among all files in this program as well as in the DIRLABM program. The DEF file and the CET input file are output from the FDCAL program. The DEF contains "deflators" which are use to convert the 1980 construction expenditure data in 1980

dollars to 1972 equivalent dollars as shown below.



The labor data is from the Bechtel data base. It contains the value in FTE's of labor of 40 occupation used to construct each of 69 electric producing technologies in on of 9 stages of construction. The labor data is normalized by the total construction dollars spent on each type of plant in each of 9 stages. The CET matrix is an output of the FDCAL program and is used as shown below.

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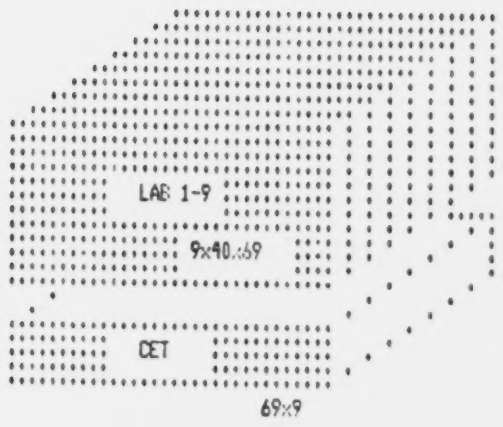
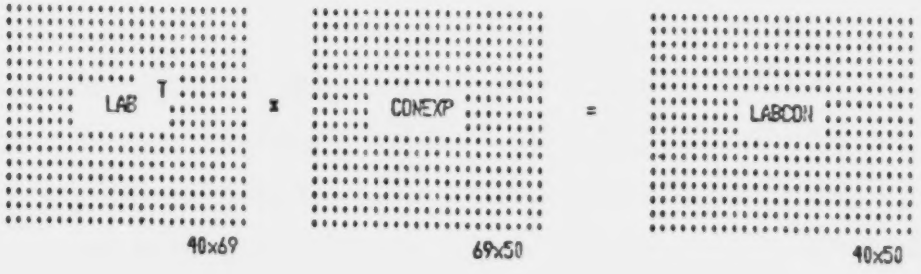


For each of the 9 stages of construction the CONEXP matrix is premultiplied by the corresponding LAB matrix. This produces 9 LABCON matrices which are summed together to produce the resulting LABCON matrix which shows the 40 occupations in each of 50 states.



The transpose of the LABCON matrix is written to a local file which must be saved for use in the DIRLABM program.

APPENDIX E

PROGRAM DESCRIPTION: DIRLABC

BASE DATA (SCENARIO INDEPENDENT)

INPUT FILES	FORMAT	SIZE	ORGANIZATION
DEF	binary file (see note)	9 x 69	column = record
CET	" "	" "	column = record
LAB1	" "	69 x 40	column = record
LAB2	" "	69 x 40	column = record
LAB3	" "	69 x 40	column = record
LAB4	" "	69 x 40	column = record
LAB5	" "	69 x 40	column = record
LAB6	" "	69 x 40	column = record
LAB7	" "	69 x 40	column = record
LAB8	" "	69 x 40	column = record
LAB9	" "	69 x 40	column = record
	SCENARIO DATA		
CONS	" "	450 X 69	column = record

Note: Each file contains a header (no. of records, record length, date and description) then binary data stored one record equals one column of a matrix.

PROGRAM DESCRIPTION

DIRLABC program performs the direct labor calculation for the construction of 69 electric generating technologies in each of 50 states, whose order is arbitary in the data base, but consistant among all files in this program as well as in the DIRLABM program. The DEF file and the CET input file are output from the FDCAL program. The DEF contains "deflators" which are used to convert the 1980 construction expenditure data in 1980 dollars to 1972 equivalent dollars.

APPENDIX F

PROGRAM DESCRIPTION: DIRLABM

BASE DATA (SCENARIO INDEPENDENT)

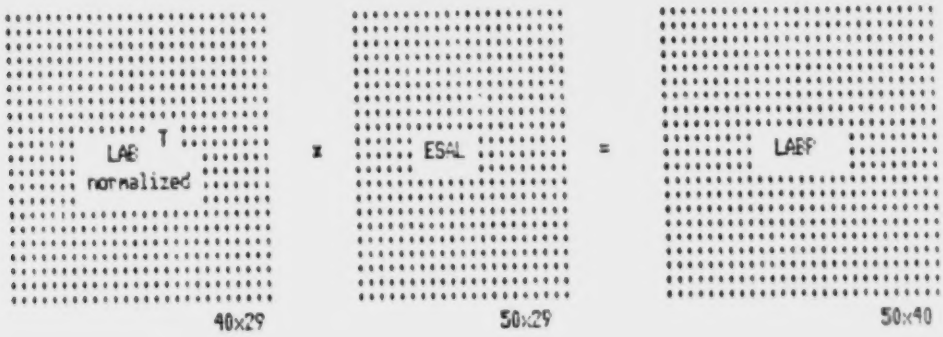
INPUT FILES	FORMAT	SIZE	ORGANIZATION
LAB	binary file (see note)	29 x 40	column = record
LABT	" "	1 x 29	column = record
TLAB	" "	3 x 40	column = record
TLABT	" "	1 x 3	column = record
MLAB	" "	4 x 40	column = record
MLABT	" "	1 x 4	column = record
	SCENARIO DATA		
ESAL	" "	50 X 29	column = record
X	" "	3 X 50	column = record
XM	" "	4 X 50	column = record
CLAB	" "	50 X 40	column = record
BTDL	" "	50 X 41	column = record

Note: Each file contains a header (no. of records, record length, date and description) then binary data stored one record equals one column of a matrix.

PROGRAM DESCRIPTION

DIRLABM program performs the direct labor calculation for the maintenance and operation of the 29 electric generating technologies, 3 transportation and 4 mining types for each of 50 states, whose order is arbitary in the data base, but consistant among all files in this program as well as in the DIRLABC program. The LAB file shows the FTE's required to operate plant in 50 states of 29 types. The LAB matrix is normalized by the LABT file which represents the typical BTU's of electric sales. The ESAL

file contains the total electric sales of 29 technologies in 50 states (BTU). This file is multiplied by the normalized LAB matrix to produce the LABP matrix which shows the labor of 40 occupations in 50 states.



The same type of mathematical operation is performed for the transportation and mining labor data. The transportation data is in the TLAB file. There are 3 types of each of 50 states. This labor data is normalized by the total ton-miles of transportation in the TLABT file. The X file contains the ton-mile transportation data for 50 states. The result of multipling the two matrices is added to the LABP matrix.

After the M&O, transportation and mining labor are added together, the construction labor data (CLAB), output of DIRLABC, is added to LABP. The 20th occupation is adjusted to 2000 hr/year FTE's by multiplying it by 1.1876. The BTDL file is read in and compared to the present calculated values. It is important to save the TDL file which contain the LABP matrix for future comparison. A hard copy of the results is available by printing LIST, a local file.

OUTPUT FILES	FORMAT	SIZE	ORGANIZATION
TDL	binary file (see note)	50 x 41	column = record

Note: Each file contains a header (no. of records, record length, date and description) then binary datae stored one record equals one column of a matrix.